CHM113 General Chemistry I (Dr. Jen)

Key

Chapter 15 Review

1) When the system **A + B ⇌ C + D** is at equilibrium,

a) the sum of the concentrations of A and B must equal the sum of the concentrations of C & D.

b) the forward reaction has stopped.

c) both the forward and the reverse reactions have stopped.

d) the reverse reaction has stopped.

e) neither the forward nor the reverse reaction has stopped.

2) Given **$2\,SO_3\,(g) \rightleftharpoons 2\,SO_2\,(g) + O_2\,(g)$** The conventional equilibrium constant expression (K_c) for the system as described by the above equation is:

a) $[SO_2]^2/[SO_3]$ b) $[SO_2]^2[O_2]/[SO_3]^2$ c) $[SO_3]^2/[SO_3]^2[O_2]$ d) $[SO_2][O_2]$ e) none of these

3) Consider the following reversible reaction. In a 3.00 liter container, the following amounts are found in equilibrium at 400 °C: 0.0420 mole N_2, 0.516 mole H_2 and 0.0357 mole NH_3. Evaluate K_c. **$N_2\,(g) + 3\,H_2\,(g) \rightleftharpoons 2\,NH_3\,(g)$**

a) 0.202 b) 1.99 c) 16.0 d) 4.94 e) 0.503

4) If the equilibrium constant for the reaction **A + 2 B ⇌ C + 5/2 D** has a value of 4.0, what is the value of the equilibrium constant for the reaction: **2 C + 5 D ⇌ 2A + 4 B** at the same temperature?

a) 0.25 b) 0.063 c) 2.0 d) 8.0 e) 16

5) At 445 °C, K_c for the following reaction is 0.020. **$2\,HI\,(g) \rightleftharpoons H_2\,(g) + I_2\,(g)$**
A mixture of H_2, I_2, and HI in a vessel at 445 °C has the following concentrations: [HI] = 2.0 M, $[H_2]$ = 0.50 M and $[I_2]$ = 0.10 M. Which one of the following statements concerning the reaction quotient, Q_c, is **TRUE** for the above system?

a) $Q_c = K_c$; the system is at equilibrium. b) Q_c is less than K_c; more H_2 and I_2 will be produced.

c) Q_c is less than K_c; more HI will be produced.

d) Q_c is greater than K_c; more H_2 and I_2 will be produced.

e) Q_c is greater than K_c; more HI will be produced.

6) Consider the gas-phase equilibrium system represented by the equation:
heat + $2\,H_2O\,(g) \rightleftharpoons 2\,H_2\,(g) + O_2\,(g)$ Given that the forward reaction is **endothermic**, which of the following changes will **decrease** the equilibrium amount of H_2O?

a) adding more oxygen b) adding a solid phase catalyst

c) increasing the temperature at constant pressure d) adding He gas

Key

7) Consider the equilibrium system: **2 ICl (s) ⇌ I_2 (s) + Cl_2 (g)**
Which of the following changes will increase the total amount of Cl_2 that can be produced?

a) removing some of the I_2 X ← pure solid so not in K_c ∴ won't impact equilibrium
b) adding more ICl X
c) removing the Cl_2 as it is formed ↳ shift toward a decrease
d) all of the above

8) Predict the direction of reaction from each of the following changes.

$2\ NO_2\ (g) + 7\ H_2\ (g) \rightleftharpoons 2\ NH_3\ (g) + 4\ H_2O\ (g)$ + heat ΔH = −993 kJ (exothermic)

a) an increase in the volume of the container. ↑V will change gas ability to collide so favor s'd with more moles of gas
b) increase in temperature ↑T so shift left away from increase left
c) removal of NH_3 ↓NH_3 so shift toward a decrease to the right
d) addition of a catalyst ⇒ No change! only imparts Ea (how gouged to ⇌ but not once at ⇌)
e) addition of 0.15 mol of helium gas ⇒ not in the eqn ∴ no impact

9) For a specific reaction, which of the following statements can be made about K, the equilibrium constant?

a) It always remains the same at different reaction conditions. ← Δ in [ ], pressure & T can change it
b) It increases if the concentration of one of the products is increased. ← the equilibrium shifts but the K_c remains constant
c) It changes with changes in the temperature. ✓
d) It increases if the concentration of one of the reactants is increased. ←
e) It may be changed by the addition of a catalyst. ← catalysts don't Δ K_c

10) For the following reaction in a sealed vessel with constant temperature was added $[SO_2]$ = 0.0100 M and $[O_2]$ = 0.0030 M. At equilibrium, $[SO_3]$ = 0.0040 M.

$2\ SO_2\ (g) + O_2\ (g) \rightleftharpoons 2\ SO_3\ (g)$

a) Calculate the K_c under these conditions.

b) Calculate the K_c of the reverse reaction at the same temperature.

11) Given the reaction, **$3\ A\ (g) + B\ (g) \rightleftharpoons 2\ C\ (g)$**

Where K_c = 0.020 and the equilibrium concentrations are 0.40 M for B and 0.0080 M for C. Determine the equilibrium concentration of A.

12) Determine the K_c for the reaction: **$2\ HF\ (aq) + C_2O_4^{2-}\ (aq) \rightleftharpoons 2\ F^-\ (aq) + H_2C_2O_4\ (aq)$**

Given the following reactions: **$HF\ (aq) \rightleftharpoons H^+\ (aq) + F^-\ (aq)$** $K_c = 6.8 \times 10^{-4}$

$H_2C_2O_4\ (aq) \rightleftharpoons 2\ H^+\ (aq) + C_2O_4^{2-}\ (aq)$ $K_c = 3.8 \times 10^{-6}$

Key

10) (a)

	$2\,SO_2$	+ O_2	$\rightleftharpoons$	$2\,SO_3$
I	0.0100	0.0030		Ø b/c no pdts initially
C	− 0.0040	− 0.0020		+ 0.0040
E	0.0060	0.0010		0.0040

$$K_c = \frac{[SO_3]^2_{eq}}{[SO_2]^2_{eq}[O_2]_{eq}}$$

△

$[O_2]$ $\quad \frac{0.0040\ mol\ SO_3}{L} \times \frac{1\ mol\ O_2}{2\ mol\ SO_3} = 0.0020\ M\ O_2$

$[SO_2]$ $\quad \frac{0.0040\ mol\ SO_3}{L} \times \frac{2\ mol\ SO_2}{2\ mol\ SO_3} = 0.0040\ M\ SO_2$

$$K_c = \frac{[0.0040]^2}{(0.0060)^2(0.0010)}$$

$$\boxed{K_c = 4.4 \times 10^3}$$

(b) $K_{reverse} = \frac{1}{K_{forward}} = \frac{1}{(4.4 \times 10^3)} = \boxed{0.0023}$

---

11) $K_c = \frac{[C]^2}{[A]^3[B]}$ ← solve for

$$[A]^3 = \frac{[C]^2}{K_c[B]} \quad \text{or} \quad [A] = \sqrt[3]{\frac{(0.0080)^2}{(0.020)(0.40)}}$$

← cubed root to cancel exponent

$$\boxed{[A] = 0.20\,M}$$

12)

desired rxn: $\boxed{2}HF(aq) + C_2O_4^{2-}(aq) \rightleftharpoons \boxed{2}F^-(aq) + H_2C_2O_4(aq)$

reactant reactant product product

given rxns:

$\boxed{\ }HF(aq) \rightleftharpoons H^+(aq) + \boxed{\ }F^-(aq)$ $\quad K_c = 6.8\times10^{-4}$

↑ reactant ✓ need multiple = 2 ; ↓ need to cancel ; ↑ product ✓ need multiple = 2

$H_2C_2O_4(aq) \rightleftharpoons 2H^+(aq) + C_2O_4^{2-}(aq)$ $\quad K_c = 3.8\times10^{-6}$

reactant → need as product so need to reverse ; ↓ need to cancel ; product → need as reactant so need to reverse

① Determine K_c for each step ✓

② Apply Hess's Law (modified)

ⓐ Identify pdts & reactants in given & desired rxns

ⓑ Reverse, if necessary. Rule: $K_{c(reverse)} = \dfrac{1}{K_{c(forward)}}$

eq. #2 $C_2O_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons H_2C_2O_4(aq)$ $\quad K_{c(reverse)} = \dfrac{1}{(3.8\times10^{-6})}$

ⓒ Multiple, if necessary. Rule: $K_{c(new)} = K_c^{\text{multiple}}$

eq. #1 $2HF(aq) \rightleftharpoons 2H^+(aq) + 2F^-(aq)$ $\quad K_{c(new)} = (6.8\times10^{-4})$

cancel

ⓓ Sum equations to make sure you get desired rxn!

$C_2O_4^{2-}(aq) + 2HF(aq) \rightleftharpoons H_2C_2O_4(aq) + 2F^-(aq) \Rightarrow$ desired rxn!

③ $K_{total} = (K_1)(K_2)$

$$K_{c\,rxn} = \left(\frac{1}{(3.8\times10^{-6})}\right)\left((6.8\times10^{-4})^2\right) = \boxed{0.12}$$